TOWARDS A TYPOLOGY IN LITERATURE STUDIES & REVIEWS IN ENGINEERING EDUCATION RESEARCH

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Conference Key Areas*: Interdisciplinary Education, Nice & Novel*
Keywords*: Literature Reviews, Engineering Education Research, Typologies, SALSA framework*

ABSTRACT

As the field of Engineering Education Research is maturing, more and more literature on Engineering Education is becoming available. Combined with increasing digitization and data analysis possibilities in the area of educational research literature, as well as a trend towards requiring more transparent and reproducible literature studies, researchers are required to adopt new and different approaches towards literature studies and reviews. Some examples of the different types are the systematic review, the critical review and the literature overview.

This paper intends to assist engineering education researchers by outlining a typology of different literature review types within the field of engineering education research. This typology is based on an elaborate analysis of published literature studies in 3 leading engineering education journals, the IEEE transactions on education, EJEE and JEE, making use of the SALSA Framework (Search, AppraisaL, Synthesis and Analysis) based on a SCOPUS search. A similar method has previously been successfully employed when creating a literature typology in health research by Booth and Grant in 2009 [1]. The characteristics of each typology will be described and suitable and relevant examples of each typology will be given. The outcomes presented in this paper will provide engineering education researchers with a valuable resource to conduct, inform, interpret and guide literature studies in their field.

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1 INTRODUCTION

1.1 Historical Perspective

Structural approaches to Engineering Education Research (EER) are relatively new. The first compendium on Engineering Education Research published by Heywood in 1985 [2] also does not refer to papers earlier than 1966. Even though the American Society for Engineering Education (ASEE) was founded in 1893, its flagship journal, the Journal of Engineering Education was only reconfigured into a pure scholarly journal in 1993. Its European sister organisation, the European Society for Engineering Education (SEFI), founded in 1973, did not launch its flagship journal, the European Journal of Engineering Education until 1985. Also, formal MSc and PhD degree programmes in Engineering Education were only launched in the U.S.A. from 2003 at Utah State University followed by Purdue and Virginia Tech in 2004 and Clemson University in 2006 [3]. In Europe, the UNESCO International Centre for Engineering Education at Aalborg University was the first to offer such a programme in 2004 [4]. This makes the field of EER a relatively young research field. From this perspective it is not strange that only in the last 10-15 years we see an increase in literature reviews on Engineering Education being published and a variety of review types emerging.

1.2 Literature Reviews

Although almost any scholarly article contains a section dedicated to literature, to show cause, relevance or need for the research reported on in the article, there is also the format of the review paper. In a review paper, typically a summary is given of the existing literature on a certain topic deemed relevant by the authors of the review with different purposes from justifying further research to providing readers with concise information. These papers are in great demand as with the increasing output of scientific publications, it is impossible for any scientist to read every paper in detail [5]. Over the last few years, systematic literature reviews in engineering education have become popular, spurred on by the 2014 article by Borrego, Foster and Froyd [6]. In their article they argue that literature reviews should mature to become more transparent in the research questions they address, where and how literature was searched for and what in- and exclusion criteria have been used.

1.3 Classification of reviews

Booth and Grant [1] show in their paper on the typology of reviews in health, that in that field many different types of reviews can exist. They identified 14 types of review, as listed in table 1. Their typology is predominantly defined by the intended aim of the paper, the audience for which it was intended, its scope and how the literature is searched, appraised, synthesized and analysed.
Within engineering education research, Borrego, Foster and Froyd [6] are so far the only ones who made a specific distinction. They distinguish, although allowing for overlap, between narrative reviews and systematic reviews. They define a narrative review as having an aim to synthesize or at minimum summarize prior work using often implicit identification methods and a systematic review having explicit

identification methods and characterized by a search, select, code and synthesis approach. Within they distinguish subtypes based on the analysis method (qualitative or quantitative) of the review and the reviewed papers. The overlap between both types, as stated by Borrego, Foster and Froyd [6], shows how difficult it is to make clear distinction between each type of review. It is impossible to create a taxonomy which would create distinctive separate groups like a family tree. Hence, the approach of Booth and Grant [1] is opting to stay with the principle of a typology, which allows overlaps in characteristics, working from the principle of concepts.

This difference in approach to reviews poked the curiosity of the authors. How similar are the types of review articles in engineering education? Do all types still occur? Are there different, new types to be defined? If so, is it possible to create a similar typology for engineering education research? To start this journey the authors looked at literature reviews published in a limited number of journals and to see what overlaps with Booth and Grant list exist.

Table 1. 14 typologies as defined by Grant and Booth [quoted verbatim from 1]

Name	Description
1.Critical review	Aims to demonstrate writer has extensively researched literature and critically evaluated its quality. Goes beyond mere description to include degree of analysis and conceptual innovation. Typically results in hypothesis or model.
2.Literature review	Generic term: published materials that provide examination of recent or current literature. Can cover wide range of subjects at various levels of completeness and comprehensiveness.
3.Mapping review/ Systematic map	Map out and categorize existing literature from which to commission further reviews and/or primary research by identifying gaps in research literature.
4.Meta-analysis	Technique that statistically combines the results of quantitative studies to provide a more precise effect of the results.
5.Mixed studies review/ Mixed methods review	Refers to any combination of methods where one significant component is a literature review (usually systematic). Within a review context it refers to a combination of review approaches for example combining quantitative with qualitative research or outcome with process studies.
6.Overview	Generic term: summary of the [medical] literature that attempts to survey the literature and describe its characteristics.
7.Qualitative systematic review/ Qualitative evidence synthesis	Method for integrating or comparing the findings from qualitative studies. It looks for ‘themes’ or ‘constructs’ that lie in or across individual qualitative studies.
8.Rapid review	Assessment of what is already known about a policy or practice issue, by using systematic review methods to search and critically appraise existing research.
9.Scoping review	Preliminary assessment of potential size and scope of available research literature. Aims to identify nature and extent of research evidence (usually including ongoing research).
10.State-of-the-art review	Tend to address more current matters in contrast to other combined retrospective and current approaches. May offer new perspectives on issue or point out area for further research.
11.Systematic review	Seeks to systematically search for, appraise and synthesis research evidence, often adhering to guidelines on the conduct of a review.

12.Systematic search and review	Combines strengths of critical review with a comprehensive search process. Typically addresses broad questions to produce 'best evidence synthesis'.
13.Systematized review	Attempt to include elements of systematic review process while stopping short of systematic review. Typically conducted as postgraduate student assignment.
14.Umbrella review	Specifically refers to review compiling evidence from multiple reviews into one accessible and usable document. Focuses on broad condition or problem for which there are competing interventions and highlights reviews that address these interventions and their results.

2 METHODOLOGY

2.1 Review paper selection

The authors opted to start this process with a systematized review as listed in table 1. They selected three high ranking engineering education journals as input for this typology attempt: the European Journal of Engineering Education (EJEE), the Journal of Engineering Education (JEE) and IEEE Transactions on Education (ToE). Using Scopus, a keyword search was carried out requiring the words "Literature" or "Review" to appear in the title, abstract or keywords for each journal on 17 March 2020. Although this may not be sufficient to catch all literature review papers published in these journals, it is expected to be sufficiently selective to be representative. This search resulted in 153 articles for EJEE, 107 articles for JEE and 157 articles for IEEE.

These lists were subsequently examined by the first author who read through each abstract and eliminated all non-literature review papers based on the abstract. As the authors did not have access through their institution to EJEE and JEE articles prior to 1995, and no literature review articles were identified in the search prior to 2000 in either journal nor in the search of ToE, it was decided to limit all articles to 2000 as a safe lower limit. The remaining 63 papers were then examined in more detail. All papers that were not a stand-alone literature review were eliminated as well as any reviews of software and standards. This resulted in nett lists of 14 articles for EJEE, 16 articles for JEE, and 7 articles for ToE published between 2003-2020, totalling 37 articles. The notion by Borrego et al. [6] that literature review articles in this young field are still rare can be confirmed. As can be seen in Fig. 1, most standalone literature reviews identified were published in the last 10 years.

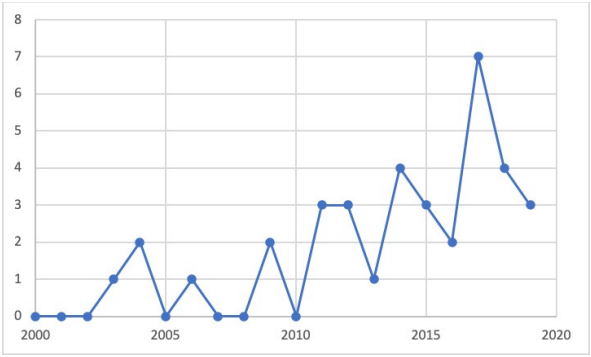

Fig. 1. Number of stand-alone review articles published in JEE, EJEE and ToE

2.2 Classification

The remaining papers were then read by the first author who for each paper recorded the aim of the paper; what review label, if any, the author of the examined paper assigned themselves and what the purpose of the review was. Based on this overview, the authors attempted to assign a typology from the list by Booth and Grant. To assist them in selecting the best typology the same SALSA framework, (Search, AppraisaL, Synthesis and Analysis) as employed by Booth and Grant [1] was used to characterize each paper. All papers included in this study are listed in Appendix A.

2.3 Limitations

The approach used in this paper has the following limitations. Firstly, the selection of search terms may mean that some literature reviews may have inadvertently been missed. Not all abstracts were sufficiently detailed and the authors were grateful for the available structured abstracts as this greatly assisted them in their search and appraisal. Secondly, only 3 engineering education journals were examined, even though the Research in Engineering Education Network (REEN) lists many more engineering education journals and also no proceedings of engineering education conferences were included which means certain types of reviews may have been overlooked altogether. Finally, the search and appraisal process for this paper would have gone more smoothly if better keywords, controlled and uncontrolled vocabularly terms were used by journals. Often literature reviews could not be identified from these, hindering the speed and accurateness of the process.

3 RESULTS

3.1 Classification analysis

All papers were initially analysed and qualified as described in section 2.2. In appendix A all articles are listed with their typologies. In table 2 the results are shown for the classifications given by the author to their review, either in the title or in the text. It can be seen from this table that there are two predominant review types: the systematic review and the literature review. Some of the other types listed can also be found in Booth and Grant [1]. These have all been marked by *.

*Table 2. Results of self-classification by authors of examined papers. Papers marked with * indicate review types listed by Booth and Grant [1].*

Classification	Number of articles	References
Systematic Review*	12	[7], [8], [9], [17], [18], [24], [26], [27], [29], [30], [34], [38]
(literature) Review*	11	[11], [14], [15], [19], [20], [21], [22], [25], [31], [36], [41]
Meta-Analysis*	2	[33], [43]
Survey	2	[37], [39]
Synthesis	2	[10], [42]
Critical Review*	1	[13]
Historical review	1	[32]
Literature Analysis	1	[16]

Meta-Literature Review	1	[35]
Narrative Review	1	[28]
Qualitative Systematic review*	1	[23]
Systematic Mapping Study*	1	[40]
None given	1	[12]

To see if the review types not listed by Booth and Grant were new types, all papers were also analysed according to the typologies described by Booth and Grant. In table 3 the results of this qualification are shown.

Table 3. Results of classification analysis using Booth and Grant's typology [1]

Typology	**Number of articles**	**References**
1.Critical review	6	[16], [28], [31], [35], [36], [41]
2.Literature review	8	[11], [12], [13], [14], [15], [22], [25], [32]
3.Mapping review/ Systematic map	2	[10], [29]
4.Meta-analysis	2	[33], [43]
6.Overview	4	[19], [20], [37], [39]
7.Qualtitative Systematic Review	1	[23]
9.Scoping Review	1	[40]
10.State-of-the-art review	1	[21]
11.Systematic review	12	[7], [8], [9], [17], [18], [24], [26], [27], [30], [34], [38], [42]

From the results in table 3, it can be seen that it was possible to classify all review within the typology of Booth and Grant. The systematic review was found to be the most popular type of review, followed closely by the literature review and the critical review.

3.2 Other observations

Out of the 37 review papers only one referred to the paper of Booth and Grant as a source of review types to select from. Most of the authors of the examined papers do not mention why they select a review method, and those who do predominantly have opted to use a systematic review and quote Borrego, Foster and Froyd [6] as the reason. Also, only nine of the review types identified by Booth and Grant were found in the papers. This is not to say that the other types of reviews do not (yet) exist in engineering education research. The purpose of some of the other typologies listed in Booth and Grant may preclude them from being published in these particular journals and may be more suited for publication in other journals or have only been published in conference papers and proceedings. Others, such as the reviews of reviews – the Umbrella review - may not yet have appeared as there are insufficient similarly themed systematic reviews to base these on. It can be expected that this type of review together with the qualitative systematic review and the meta-analysis will become more prevalent in the next few years.

A final observation is that the ToE has published less literature reviews than the EJEE or the JEE. This may in part be due to the scope of the journal and in part because the strict page limit (6 pages after which charges apply) may make the journal less attractive for the usually more elaborate review papers.

4 SUMMARY AND FUTURE RESEARCH

The typology as used by Booth and Grant appears to be inclusive enough to also be used in engineering education research. It goes further than the classification based on methods only as proposed by Borrego, Foster and Froyd [6] and may therefore be more conductive in use. To investigate this further more engineering education literature must be examined. This should include the engineering journals as listed on the REEN website as well as the papers published in the proceedings of the major engineering education (research) conferences such as ASEE and SEFI. It would also be worthwhile to investigate if other typologies of literature reviews exist in the general field of education as well as other fields to ensure completeness. Also, the authors echo the call by Booth and Grant [1] in their paper for the need of “an internationally agreed set of discrete, coherent and mutually exclusive review types” to assist researchers in any field.

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APPENDIX A: OVERVIEW OF CLASSIFIED LITERATURE REVIEWS

Title	Authors	Journal	Year	Volume, pages, doi	Self-Classification	G&B classification [1]
The study of grit in engineering education research: a systematic literature review [7]	Direito, I., Chance, S., Malik, M.	EJEE	2019	10.1080/03043797.2019.1688256	Systematic Review	Systematic Review
Evaluation of competency methods in engineering education: a systematic review [8]	Leandro Cruz, M., Saunders-Smits, G.N., Groen, P.	EJEE	2019	10.1080/03043797.2019.1671810	Systematic Review	Systematic Review
A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement [9]	Morelock, J.R.	EJEE	2017	42 (6), pp. 1240-1262	Systematic Review	Systematic Review
Explaining student success in engineering education at Delft University of Technology: a literature synthesis [10]	van den Bogaard, M.	EJEE	2012	37 (1), pp. 59-82	Literature Synthesis	Mapping review
Towards characterising design-based learning in engineering education: A review of the literature [11]	Puente, S.M.G., van Eijck, M.V., Jochems, W.	EJEE	2011	36 (2), pp. 137-149	Literature Review	Literature Review
Demarcating advanced learning approaches from methodological and technological perspectives [12]	Horváth, I., Peck, D., Verlinden, J.	EJEE	2009	34 (6), pp. 465-485	None given	Literature Review
Learning theories and assessment methodologies - an engineering educational perspective [13]	Hassan, O.A.B.	EJEE	2011	36 (4), pp. 327-339	Critical Review	Literature Review
Fostering creative engineers: A key to face the complexity of engineering practice [14]	Zhou, C.	EJEE	2012	37 (4), pp. 343-353	Literature Review	Literature Review
Why research-informed teaching in engineering education? A review of the evidence [15]	Bubou, G.M., Offor, I.T., Bappa, A.S.	EJEE	2017	42 (3), pp. 323-335	Literature Review	Literature Review
About, for, in or through entrepreneurship in engineering education [16]	Mäkimurto-Koivumaa, S., Belt, P.	EJEE	2016	41 (5), pp. 512-529	Literature Analysis	Critical review
The use of motivation theory in engineering education research: a systematic review of literature [17]	Brown, P.R., McCord, R.E., Matusovich, H.M., Kajfez, R.L.	EJEE	2015	40 (2), pp. 186-205	Systematic Review	Systematic Review
An overview of game-based learning in building services engineering education [18]	Alanne, K.	EJEE	2016	41 (2), pp. 204-219	Systematic Review	Systematic Review
New trends in web-based learning: Objects, repositories and learner engagement [19]	MacLaren, I.	EJEE	2004	29 (1), pp. 65-71	Review	Overview
A review of literature on employability skill needs in engineering [20]	Markes, I.	EJEE	2006	31 (6), pp. 637-650.	Literature Review	Overview
A retrospective on undergraduate engineering success for underrepresented minority students [21]	May, G.S., Chubin, D.E.	JEE	2003	92 (1), pp. 27-39	Literature Review	State-of-the-Art Review
Does active learning work? A review of the research [22]	Prince, M.	JEE	2004	93 (3), pp. 223-231	Review	Literature Review
Boundary Spanning and Engineering: A Qualitative Systematic Review [23]	Jesiek, B.K., Mazzurco, A., Buswell, N.T., Thompson, J.D.	JEE	2018	107 (3), pp. 380-413	Qualitative Systematic Review	Qualitative Systematic Review

Entrepreneurship Assessment in Higher Education: A Research Review for Engineering Education Researchers [24]	Huang-Saad, A.Y., Morton, C.S., Libarkin, J.C.	JEE	2018	107 (2), pp. 263-290	Systematic Review	Systematic Review
A Review of Competency-Based Learning: Tools, Assessments, and Recommendations [25]	Henri, M., Johnson, M.D., Nepal, B.	JEE	2017	106 (4), pp. 607-638	Review	Literature Review
Engineering Thinking in Prekindergarten Children: A Systematic Literature Review [26]	Lippard, C.N., Lamm, M.H., Riley, K.L.	JEE	2017	106 (3), pp. 454-474	Systematic Review	Systematic Review
What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review [27]	Passow, H.J., Passow, C.H.	JEE	2017	106 (3), pp. 475-526	Systematic Review	Systematic Review
Systematic literature reviews in engineering education and other developing interdisciplinary fields [28]	Borrego, M., Foster, M.J., Froyd, J.E.	JEE	2014	103 (1), pp. 45-76	Narrative Review	Critical Review
What is the state of the art of systematic review in engineering education? [29]	Borrego, M., Foster, M.J., Froyd, J.E.	JEE	2015	104 (2), pp. 212-242	Systematic Review	Mapping Review
Engineers at Play: Games as Teaching Tools for Undergraduate Engineering Students [30]	Bodnar, C.A., Anastasio, D., Enszer, J.A., Burkey, D.D.	JEE	2016	105 (1), pp. 147-200	Systematic Review	Systematic Review
Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies [31]	Borrego, M., Henderson, C.	JEE	2014	103 (2), pp. 220-252	Review	Critical Review
Hybrid Learning: An integrative approach to engineering education [32]	Jamison, A., Kolmos, A., Holgaard, J.E.	JEE	2014	103 (2), pp. 253-273	Historical review	Literature Review
The impact of flipped classrooms on student achievement in engineering education: A meta-analysis of 10 years of research [33]	Lo, C.K., Hew, K.F.	JEE	2019	108 (4), pp. 523-546	Meta-Analysis	Meta-Analysis
Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams: A research review [34]	Borrego, M., Karlin, J., Mcnair, L.D., Beddoes, K.	JEE	2013	102 (4), pp. 472-512	Systematic Review	Systematic Review
The informed design teaching and learning matrix [35]	Crismond, D.P., Adams, R.S.	JEE	2012	101 (4), pp. 738-797	Meta-Literature Review	Critical Review
Engineering instructional development: Programs, best practices, and recommendations [36]	Felder, R.M., Brent, R., Prince, M.J.	JEE	2011	100 (1), pp. 89-122	Literature Review	Critical Review
A survey and evaluation of simulators suitable for teaching courses in computer architecture and organization [37]	Nikolic, B., Radivojevic, Z., Djordjevic, J., Milutinovic, V.	ToE	2009	52 (4), art. no. 4967893, pp. 449-458	Survey	Overview
A Systematic Literature Review on Teaching and Learning Introductory Programming in Higher Education [38]	Medeiros, R.P., Ramalho, G.L., Falcao, T.P.	ToE	2019	62 (2), art. no. 8447543, pp. 77-90	Systematic Review	Systematic Review
Approaches and tools used to teach the computer input/output subsystem: A survey [39]	Larraza-Mendiluze, E., Garay-Vitoria, N.	ToE	2015	58 (1), art. no. 6777580	Survey	Overview
Cloud Computing for Education: A Systematic Mapping Study [40]	Baldassarre, M.T., Caivano, D., Dimauro, G., Gentile, E., Visaggio, G.	ToE	2018	61 (3), art. no. 8283623, pp. 234-244	Systematic Mapping Study	Scoping Review
Review of computer vision education [41]	Bebis, G., Egbert, D., Shah, M.	ToE	2003	46 (1), pp. 2-21	Review	Critical Review

The Underrepresentation of Women in Computing Fields: A Synthesis of Literature Using a Life Course Perspective [42]	Main, J.B., Schimpf, C.	ToE	2017	60 (4), art. no. 7953503, pp. 296-304	Synthesis	Systematic Review
Preparing ICT Graduates for Real-World Challenges: Results of a Meta-Analysis [43]	Pažur Aničić, K., Divjak, B., Arbanas, K.	ToE	2017	60 (3), art. no. 7795180, pp. 191-197	Meta-Analysis	Meta-Analysis